Engineering Considerations For Using Geothermal Systems at Contaminated Sites

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Course Objectives

1. Provide an understanding of geothermal design principles as they relate to potential environmental issues
2. How environmental conditions impact the design of geothermal systems
3. Discuss feasibility of installing geothermal systems at impacted and MCP sites.

Why Do Geothermal At All

- **Electricity at $.06/kwh---cop at 3.5**
  .16/kwh x kw/3,412btu x 100,000btu/therm x 1/cop =

  $1.33/therm

- **Natural gas at $1.78/therm at 80% AFUE**
  1.78/therm x 1/afue =

  $2.23/therm

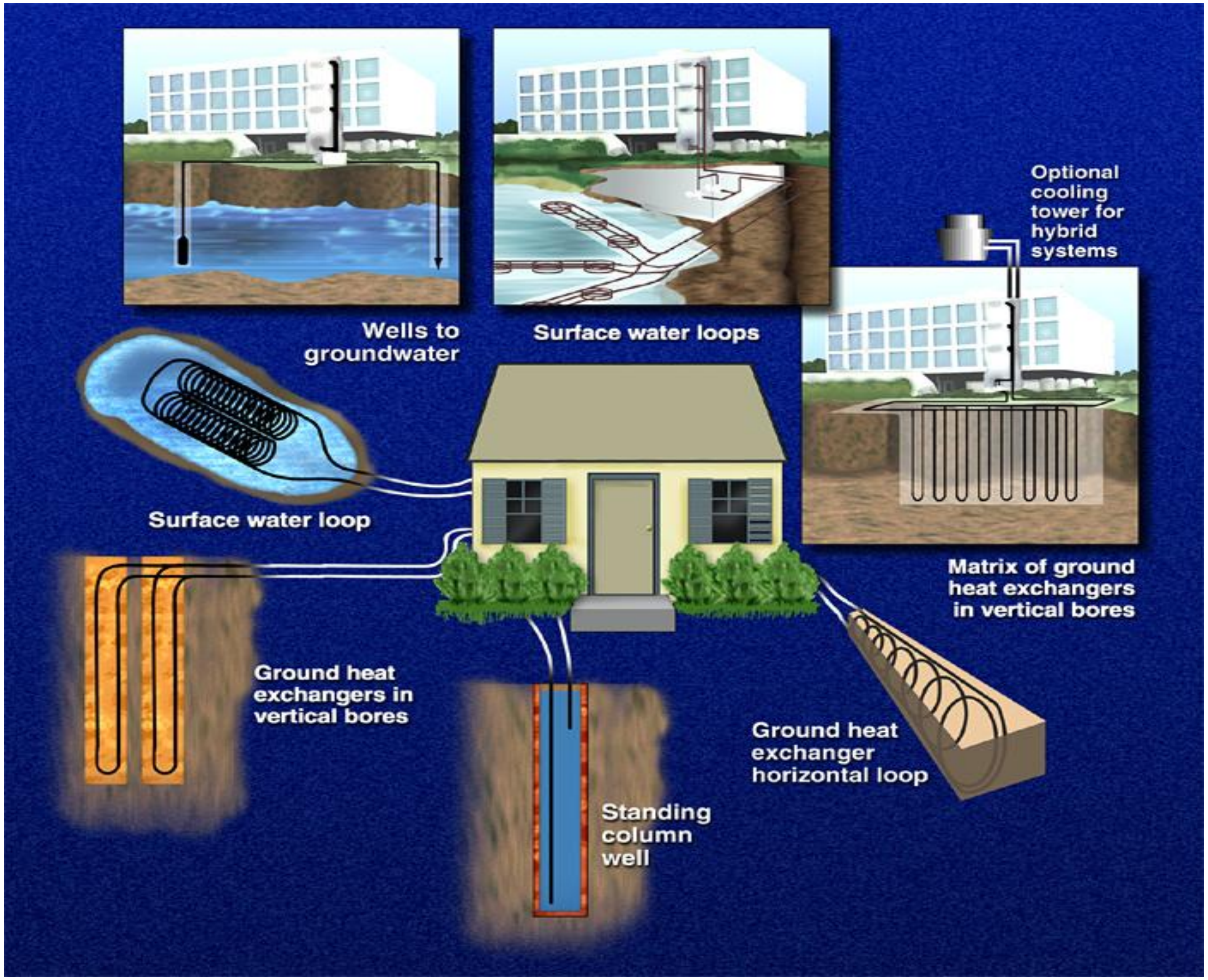
Savings = 40% and also 30% tax credit and accelerated depreciation (can pay for the ground heat exchanger).

Design Procedure

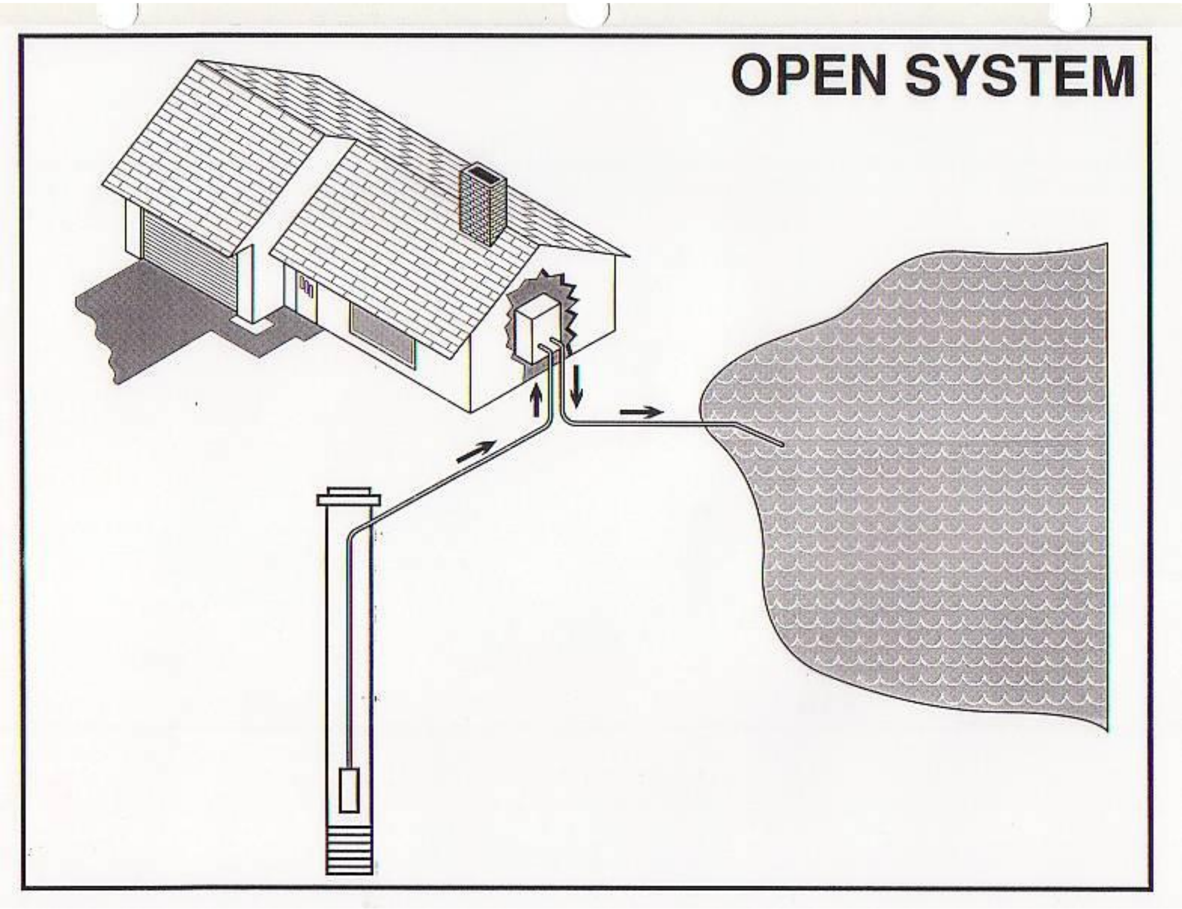
- Determine the heating/cooling loads (Btuh)
- Select heat pump size
- Estimate the building's energy requirement
- Estimate the ground heat exchanger loads
  - Annual load
  - Design month's load

Size drives the type of heat exchanger

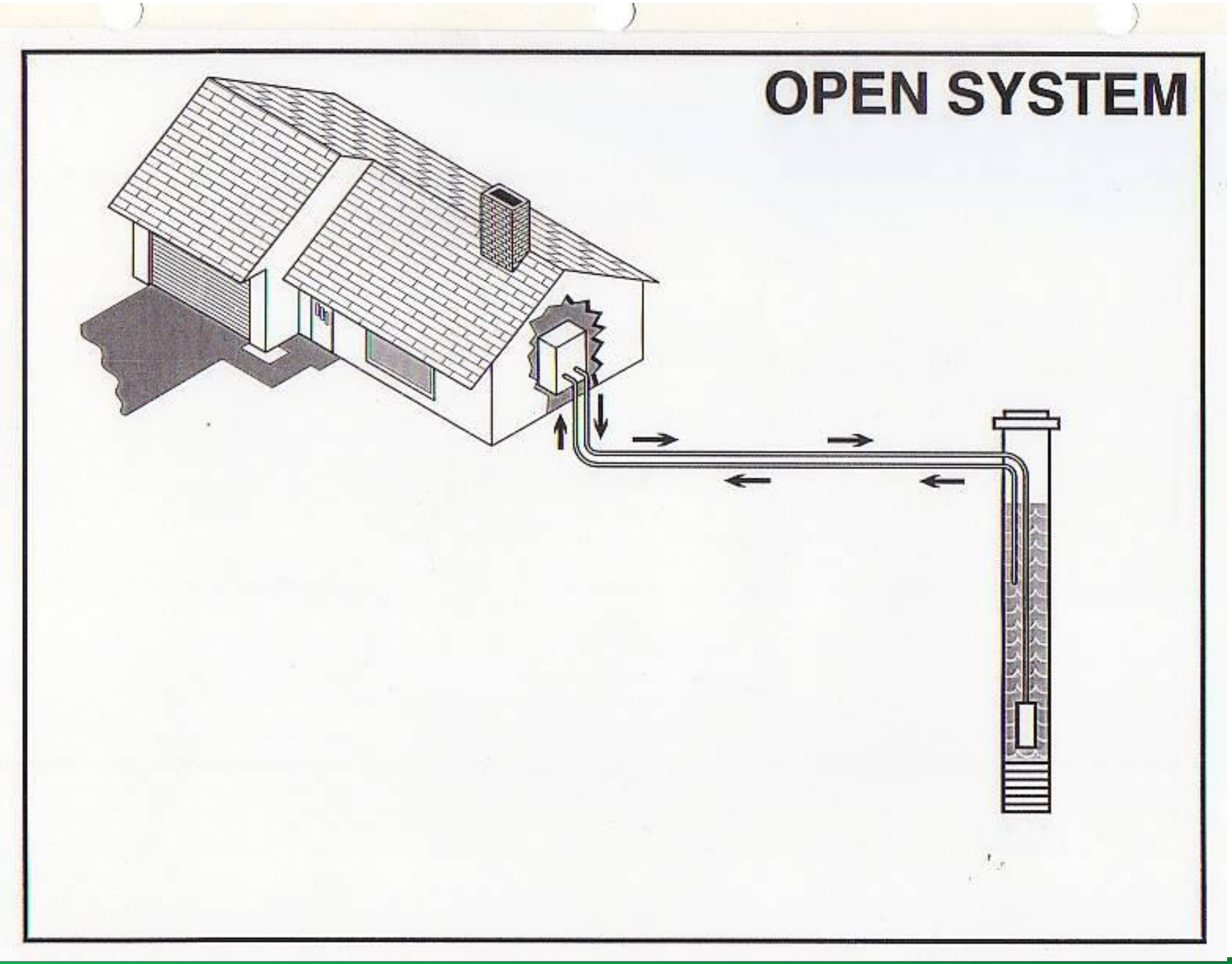
GSHP Types


Optional cooling tower for hybrid systems
Wells to groundwater
Surface water loops
Surface water loop
Matrix of ground heat exchangers in vertical bores
Ground heat exchangers in vertical bores
Ground heat exchanger horizontal loop
Standing column well

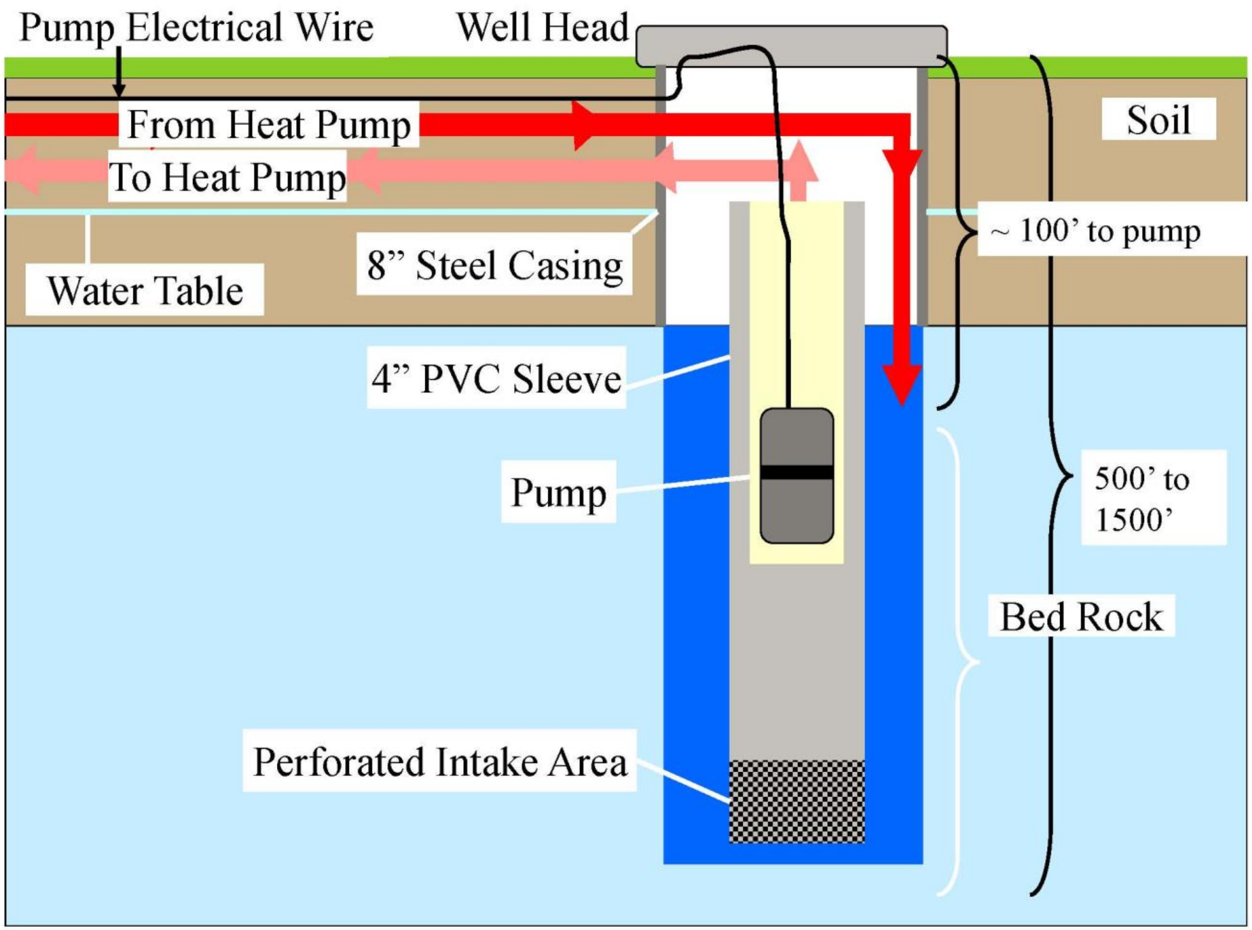
Open Loop Example



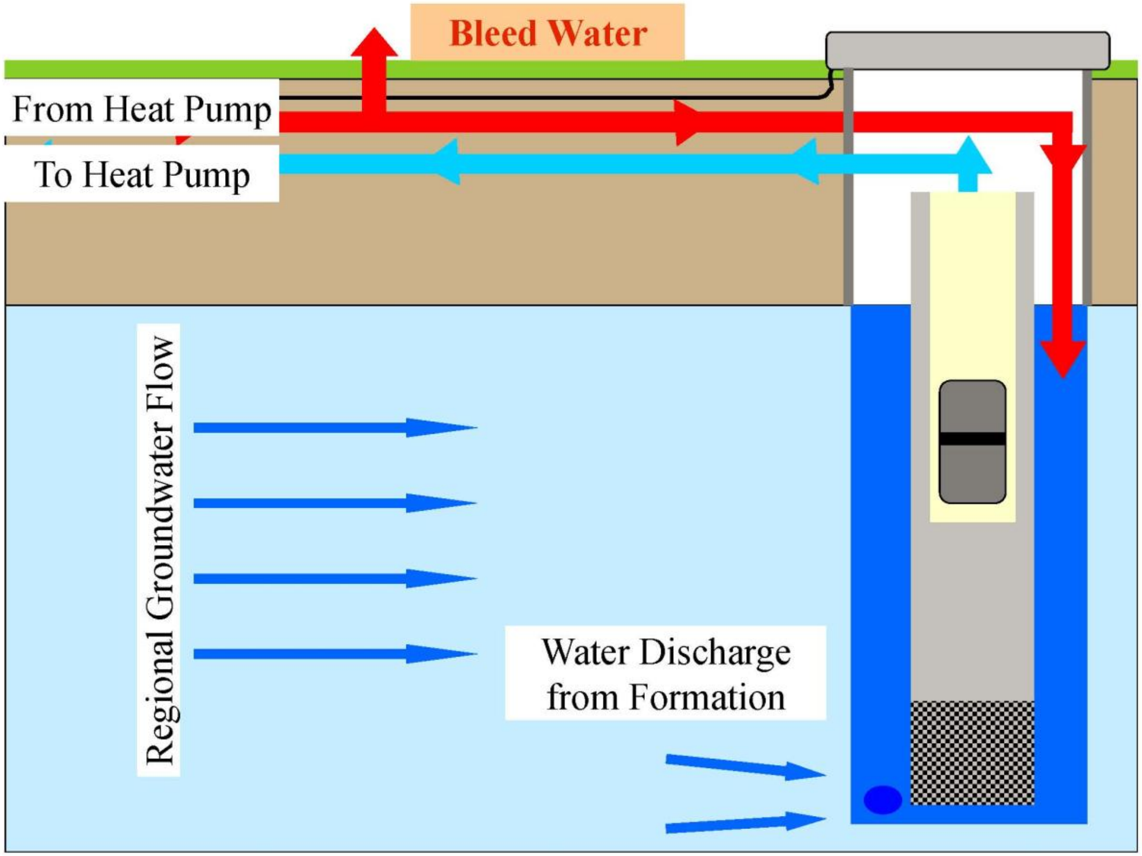
Standing Column Example



Standing Column Example



Standing Column Bleed



Using Pond as the Heat Exchanger

Closed Loop System Configurations

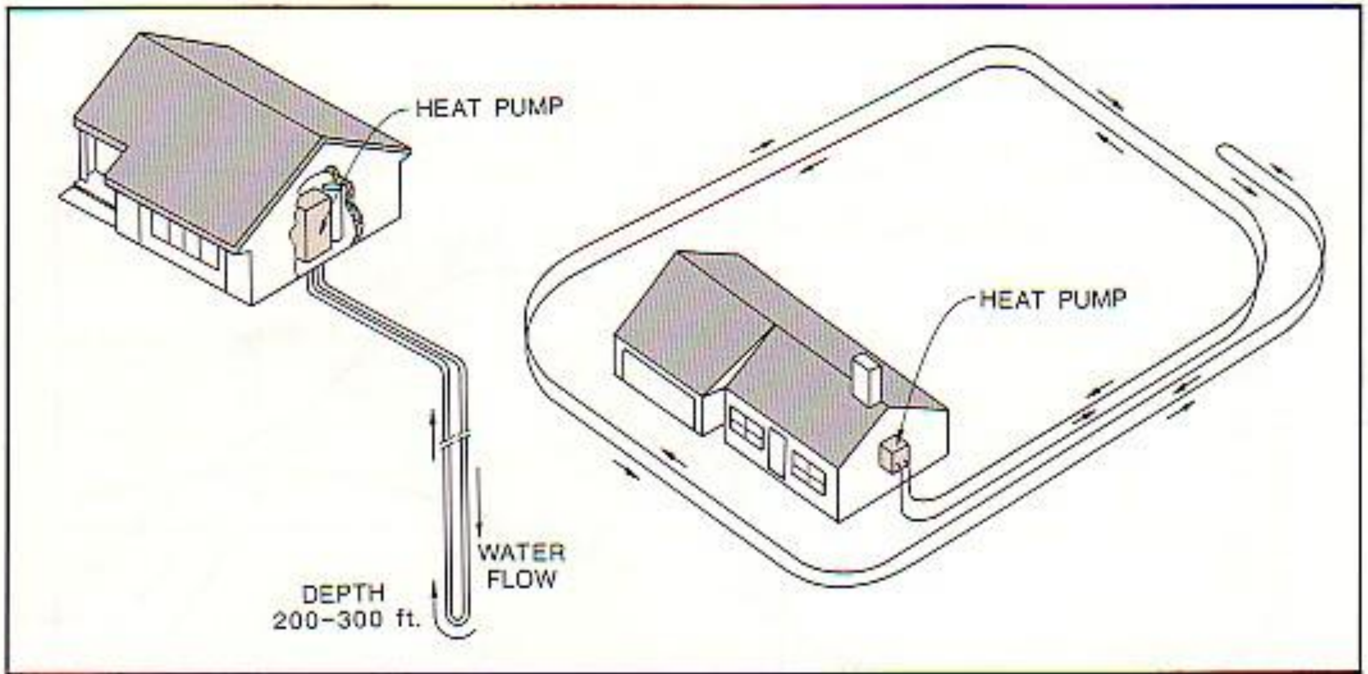
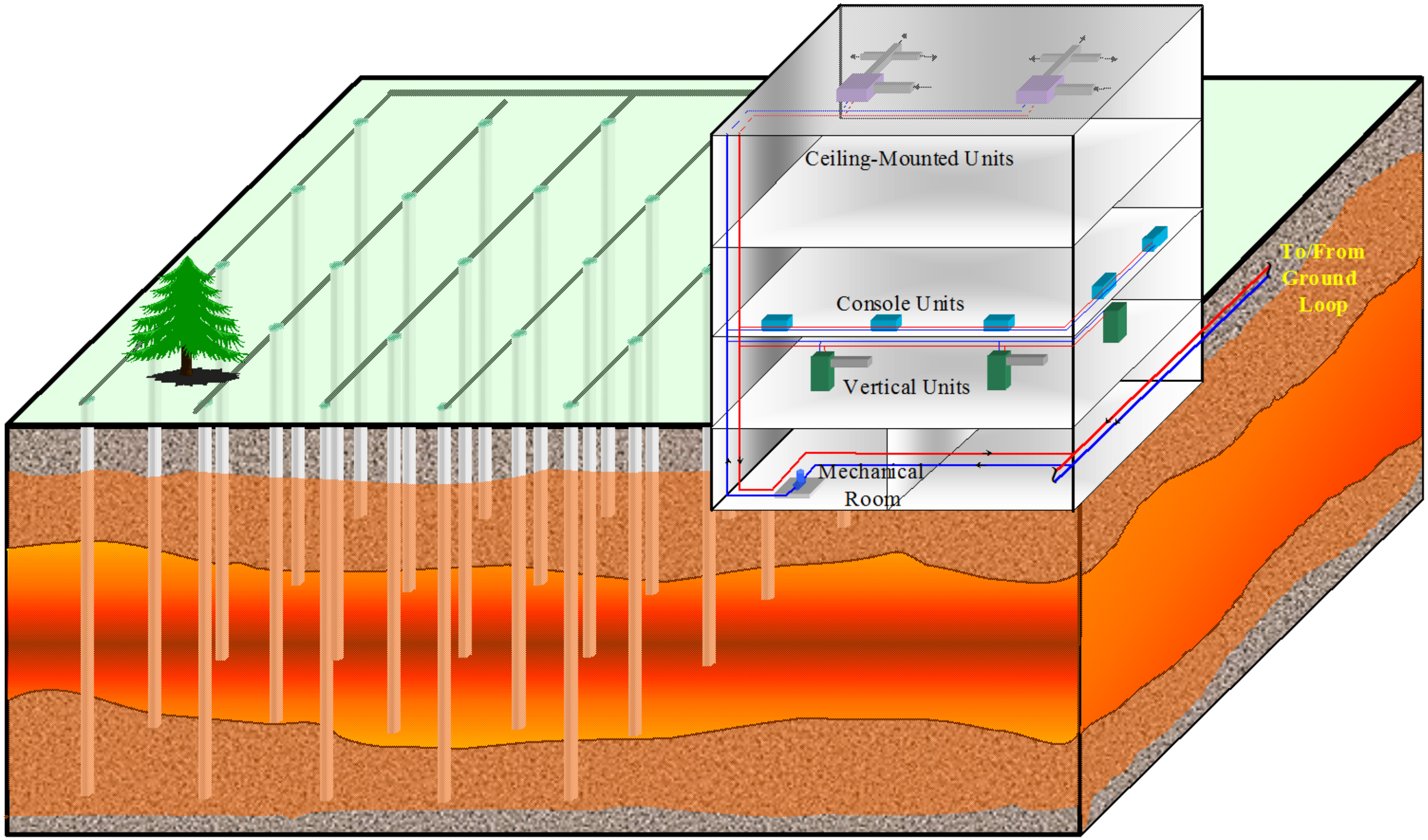


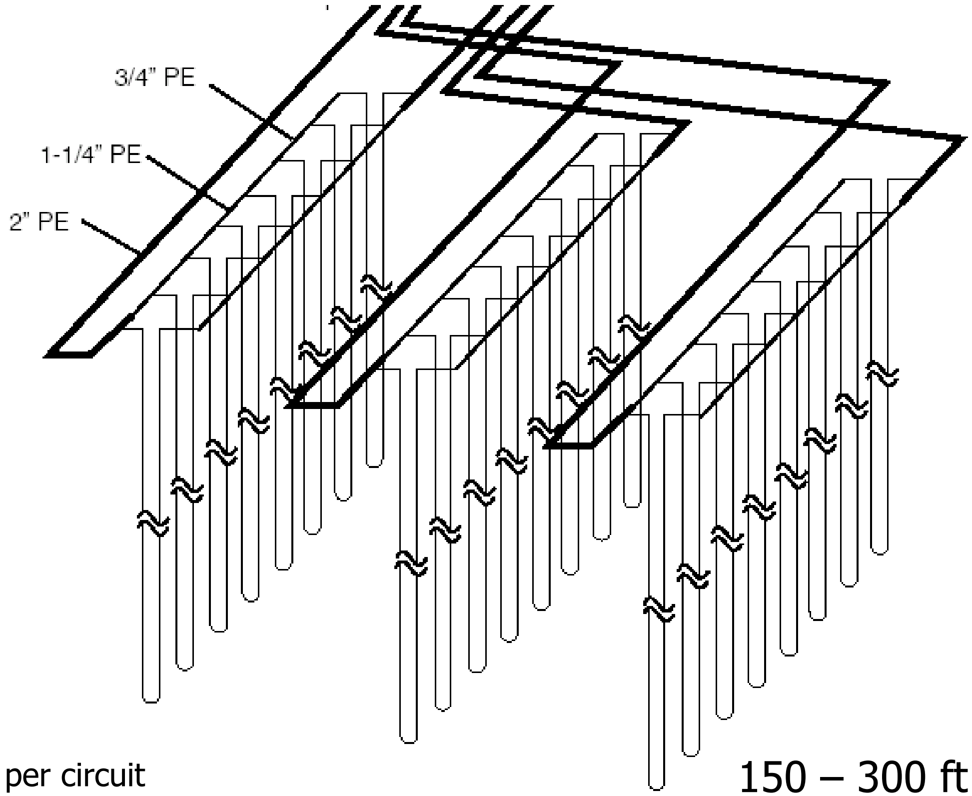
FIGURE 1.3: System Configurations

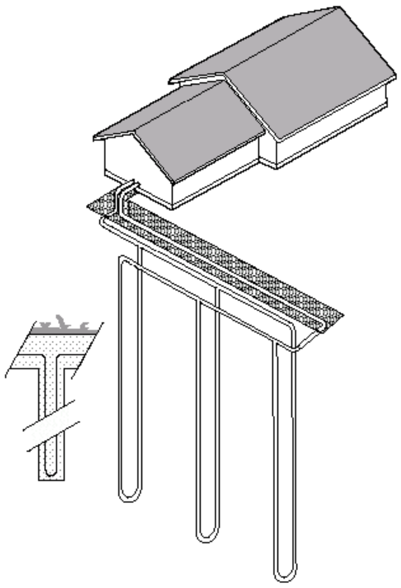
Slinky Installation for Shallow Excavation Limitations

Bore Field Example



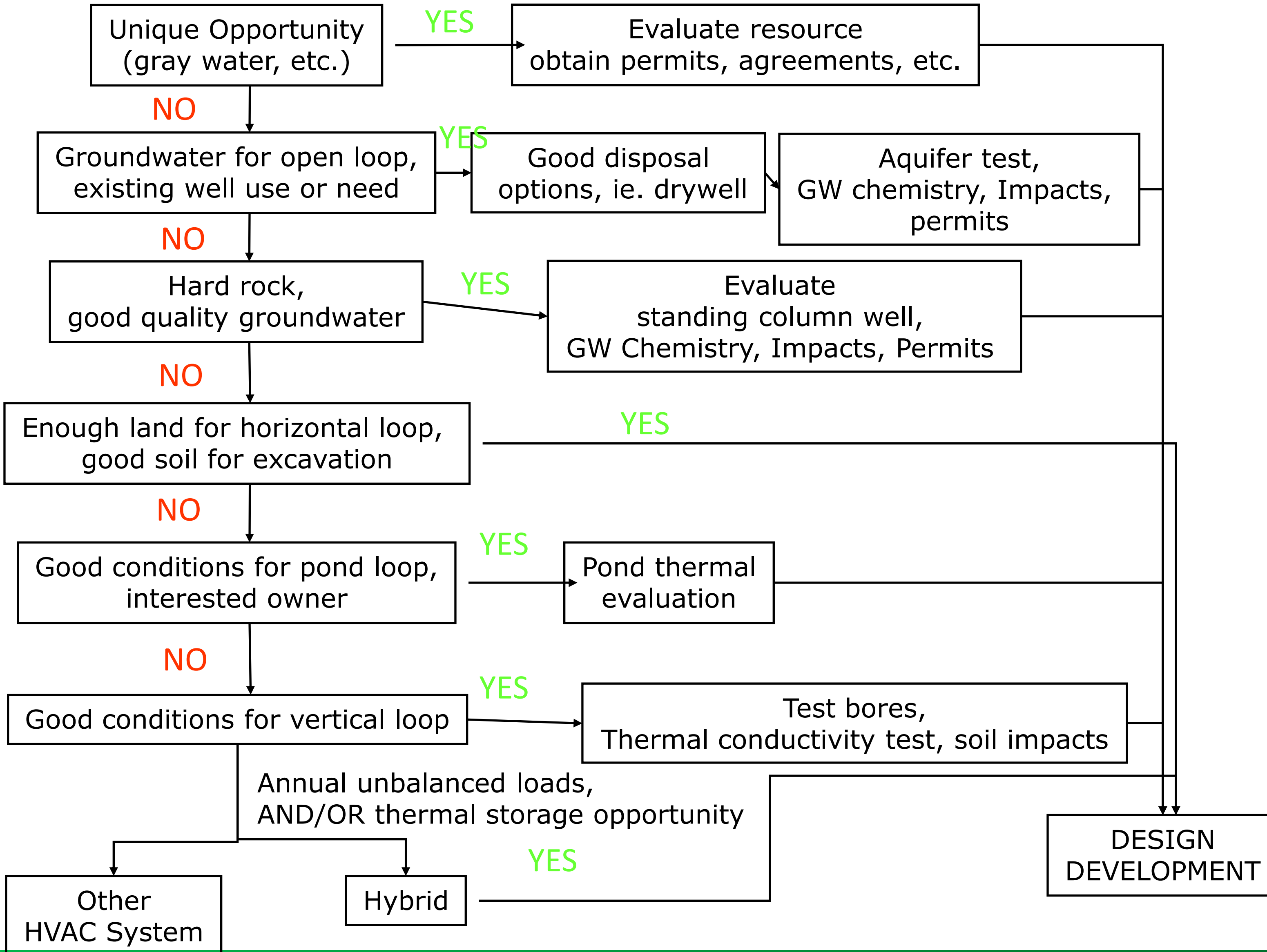
System Construction – Vertical Loops





1 bore per circuit
u-tubes can range in diameter from ¾ to 1 ¼ inch
(1-inch is most common)

150 – 300 ft typical depth
Reverse-return piping arrangement



Unique Opportunity (gray water, etc.)
YES
Evaluate resource obtain permits, agreements, etc.
NO
Groundwater for open loop, existing well use or need
YES
Good disposal options, ie. drywell
Aquifer test, GW chemistry, Impacts, permits
NO
Hard rock, good quality groundwater
YES
Evaluate standing column well, GW Chemistry, Impacts, Permits
NO
Enough land for horizontal loop, good soil for excavation
YES
NO
Good conditions for pond loop, interested owner
YES
Pond thermal evaluation
NO
Good conditions for vertical loop
YES
Test bores, Thermal conductivity test, soil impacts
Annual unbalanced loads, AND/OR thermal storage opportunity
YES
DESIGN DEVELOPMENT
Other HVAC System
Hybrid

Rules of Thumb for each Geothermal System Type

- Open Loop (Pump and Dump) – 3 gpm/ton
- Vertical Closed Loop- 150 ft to 200 ft per ton
- Horizontal Closed Loop - 200 ft to 500 ft
- Standing Column Well – 30 tons per well

Perspective - Examples of Heating/Cooling a 2,500 s.f. House for each Geothermal System Type

- Open Loop (Pump/injection) – a 21 gpm well
- Vertical Closed Loop – 3 wells (400 ft)
- Horizontal Closed Loop – (Slinky 200 ft to 300 ft)
- Standing Column Well – 1 well (400 ft with bleed)

Examples of Heating/Cooling a 40,000 s.f. Building for each Geothermal System Type

- Open Loop (Pump and Dump) – a 300 gpm well
- Vertical Closed Loop – 36 wells (500 ft)
- Horizontal Closed Loop - 2,000 ft (slinky)
- Standing Column Well – 3 wells (1,600 ft)

Evaluate Existing Environmental Conditions

1. Avoid Costly Mistakes
2. Protection of Sensitive Receptors
3. May render some type of geothermal systems not feasible

Environmental Issues Evaluation Process

1. The type of ground exchanger (open, closed, standing column well) drives the study
2. Existing environmental conditions
3. Review Existing Reports, if available
4. Review On-line Databases (MassDEP Searchable List)
5. Are there Environmental Issues at other sites in the area
6. Install Test Well to determine site geology
7. Examine Permitting Requirements-NPDES, UIC, Groundwater Discharge
8. May require water pre-testing and/or treatment
9. If soil or groundwater contamination, what is the extent.

Installation Standards Help Minimize Environmental Impacts

1. International Ground Source Heat Pump Association (IGSHPA)
2. National Groundwater Association (NGWA)

Regulatory Requirements May Render GSHP Infeasible

- Check with the local Board of Health to determine whether a local well permit is also required for your type of geothermal well. (Hingham example)
- Check with the local plumbing inspector to determine whether town allows the dual use.
- Dual use is not typically approved for commercial geothermal applications.

Open Loop and Related Environmental Issues

Open Loop

1. Must have understanding of hydrogeology.
2. Effects on aquifer both extraction and injection.
3. Must have understanding of water chemistry.
4. Must understand permit requirements.

Key Environmental Concerns

- Improperly constructed boreholes that could possibly serve as channels for contamination from surface to subsurface or from one aquifer to another
- Rate of water withdrawal may affect groundwater supply (Boise Example)
- Reinjection of water into different aquifer

Water Testing Requirements

- Tables located in Guidelines for Ground Source Heat Pump Wells-Underground Injection Control Program December 2013
- Examples include arsenic, lead, vinyl chloride, Xylenes, etc.
- May trigger treatment requirements or notification
- Design may include additives or treatment of contaminants prior to discharge which adds cost to the GSHP system.

Other Design Requirements

- Requires 90 to 120 day post system startup sampling
- Level sensors required in discharge wells to prevent overflow

Open Loop

Advantages

- Low cost, especially for large loads and residential applications that need a drinking water well
- Water well drilling technology is well-established
- Stable source temperature
- Standing column well option in certain circumstances

Disadvantages

- Water quality dependent
  - Scaling
  - Corrosion
  - Iron bacteria, well fouling
- Water disposal
- Laws and regulations
- Permits, water rights

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Equipment and Design Problems

Open-Loop System

The two most often encountered problems are inadequate flow in the production well and plugging that causes pressure build-up in the injection well. Other maintenance issues include the need to clean or rework production and injection wells and the need for chemical treatment of injected water to control scaling or bacterial growth that plugs the injection wells

The principal cause appears to be iron bacteria and, where a mature colony is established, extremely difficult to eliminate. The next most common problem associated with open loop systems is pump failure.

Potential Iron Fouling Issues

Iron sludge from a blocked strainer

Pump Test Required for Open Loop Systems

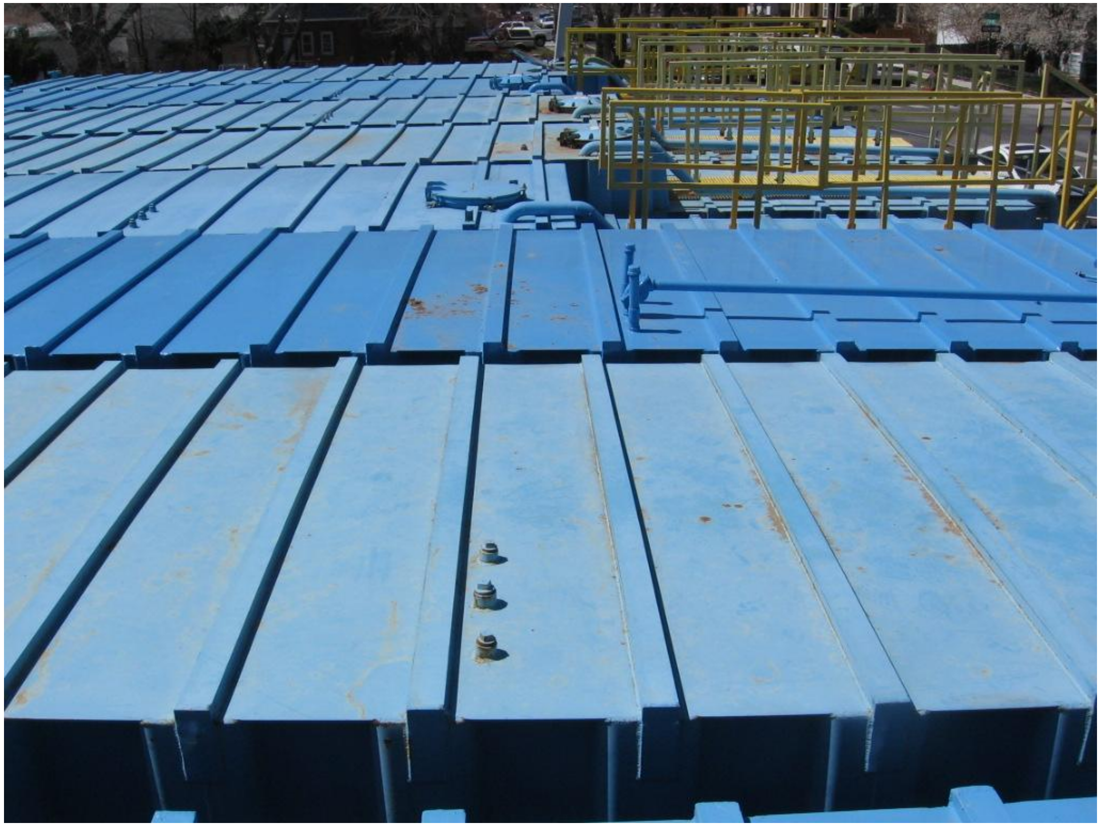
- Obtain design flow rates
- Obtain water chemistry data (needed for permit and possible treatment design)
- Test requires permits (allow time to obtain permit)

Investigate reuse options

- Reuse of bleed water in facility applications
- Discharge drywell system (UIC)
- Discharge to surface water (NPDES permitting)

Pump Test Water Disposal Issues

Pump Test Equipment



Pump Test Equipment

Borehole Excavate Disposal Issues

- If cannot be reused on site, must properly dispose off-site
- Soil sampling required.
- Could trigger notification requirement

Closed Loop Systems

Key Environmental Concerns

- Antifreeze leaks that could migrate to groundwater
- Improperly constructed boreholes that could possibly serve as channels for contamination from surface to subsurface or from one aquifer to another

Regulatory Requirements

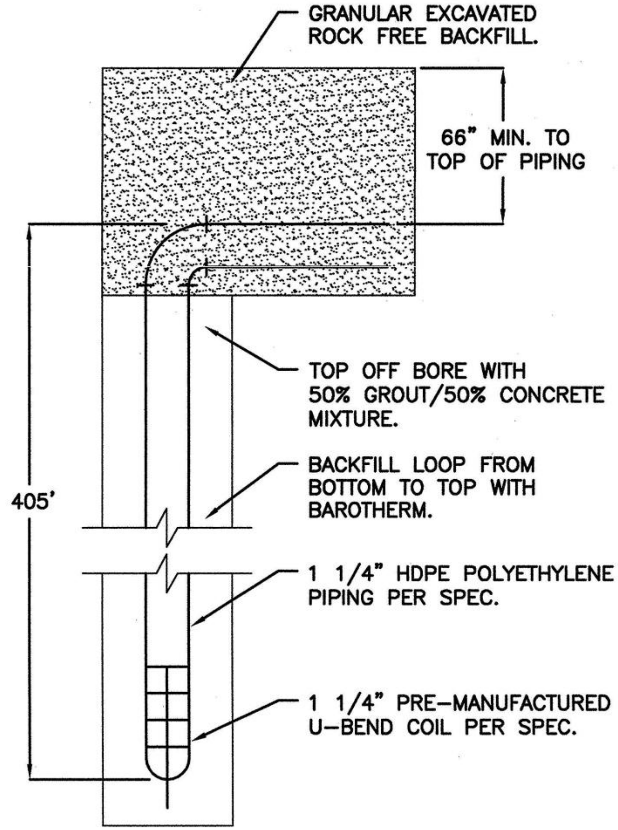
- UIC permit
- Certified Well Driller
- Shall be located at least 10 feet from potable water and sewer lines.
- The GSHP system shall have an automatic shutdown device(s) to minimize antifreeze leaks in the event of a pressure/fluid loss (usually operates 30 psi).
- Signage-type of antifreeze used

Other Requirements

- Closed-loop shall be located at least 25 feet from potential sources of contamination.
- Closed-loop shall be located at least 50 feet from private potable water supply wells
- Closed loop shall not be permitted within the Zone I of public water supply wells.
- Closed-loop shall be located at least 10 feet from surface water bodies.

System Construction Vertical Loops

- Installed by standard drilling methods
  - Auger: soils, relatively shallow holes
  - Mud-rotary: soft sediments and sedimentary rocks
  - Air-rotary: soft to hard relatively dry rocks
  - Air-hammer: hard rock
  - Cable-tool: hard rock, deep holes (slow drilling)
  - Sonic drilling: high drilling rates in most materials
- Loop (or borehole heat exchanger) is rolled off a reel into borehole
- Borehole is grouted from the bottom to the top with a “tremie pipe” to insure a good seal
  - Standard bentonite grout
  - Thermally-enhanced grouts (bentonite/sand mixture)



BORE-HOLE DETAIL

SCALE: N.T.S.

Bore Field Example

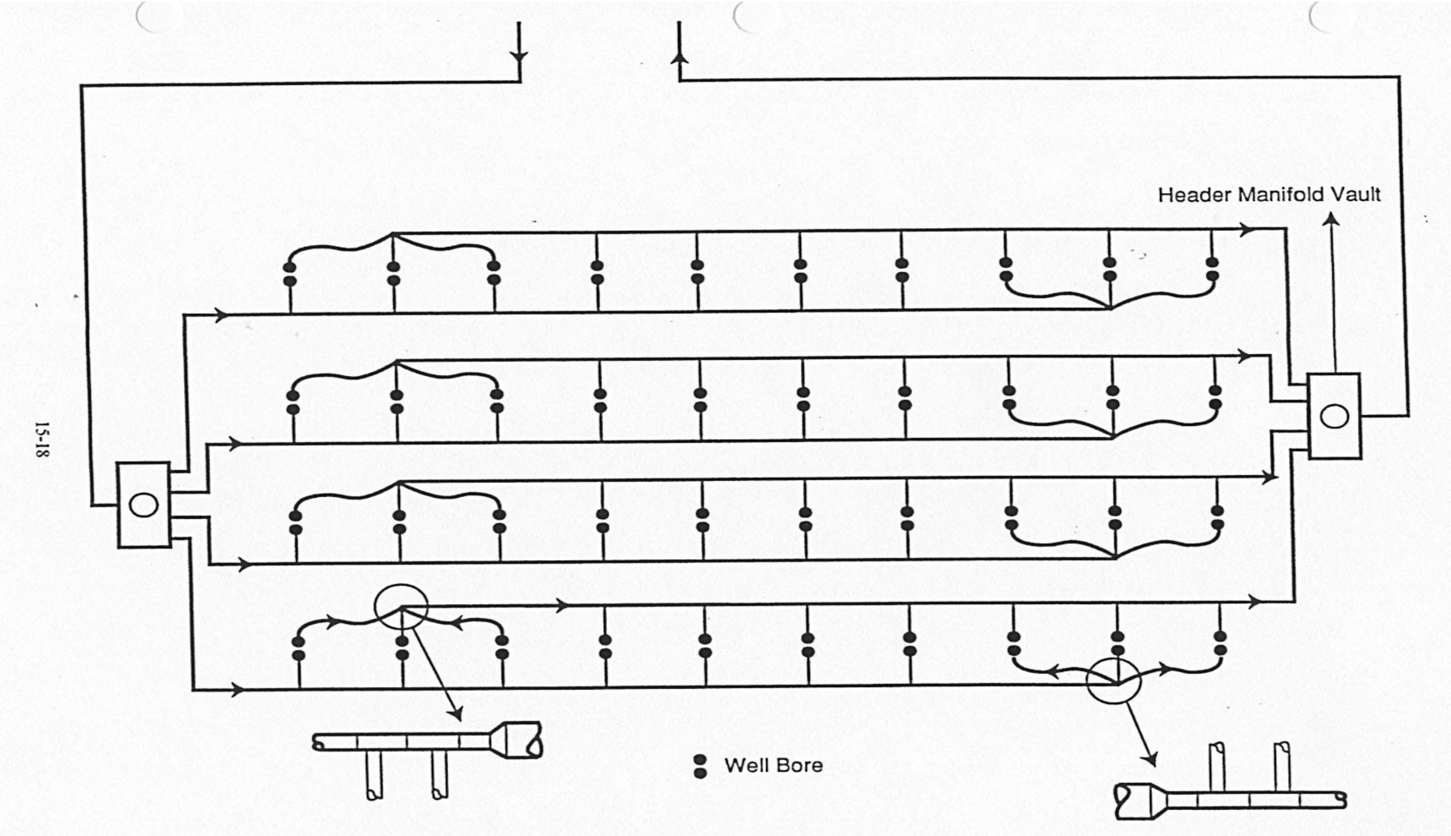


Figure 15.11 Diagram of Borefield with Manifold Vault.

Sediment and Stormwater Run-off From the Site

Header Loop Example

Approved Antifreeze

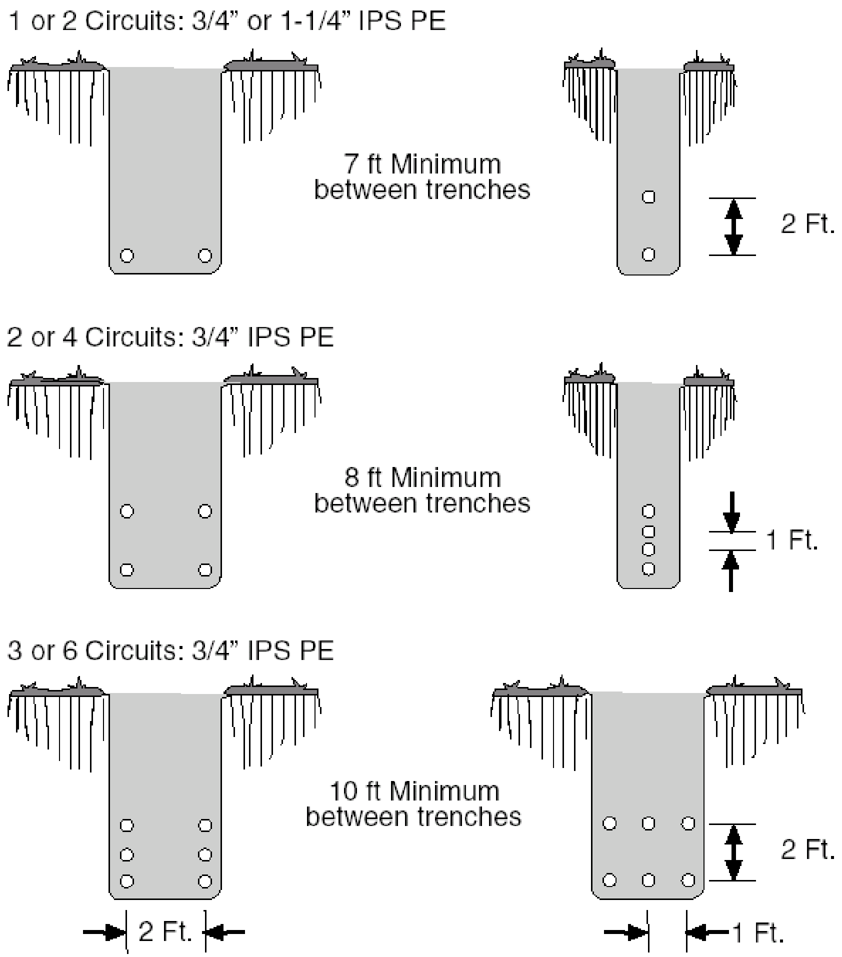
- Propylene glycol (CAS No. 57-55-6) and ethanol (CAS No. 64-17-5) are the only acceptable antifreeze additives for closed-loop GSHP wells
- All other antifreeze chemicals and denaturants must be approved by MassDEP prior to use.
- Release of 10 pounds of ethanol to the ground surface or groundwater is considered a reportable release of a hazardous material per the Massachusetts Contingency Plan (310 CMR 40.0000). ie. 7.6 gallons of water/ethanol solution would meet the reportable release threshold

Surface Containment along Borehole

1. Grouting with Tremie under pressure from bottom to top.
2. Provides seal from ground surface to aquifer to prevent entry of potentially contaminated surface water into the formation
3. Provides separation between aquifers

Trailer mounted grout unit

System Construction
Horizontal Loops



- **4 – 6 ft burial depth**
- **Consider for large open areas such as athletic fields**
- **AUL Sites (need soil management plan)**
- **Sites with GW impacts only**

Borehole Thermal Testing for Closed Loops

- Reducing the costs due to uncertainty
- Procedure

  Test bore hole drilled

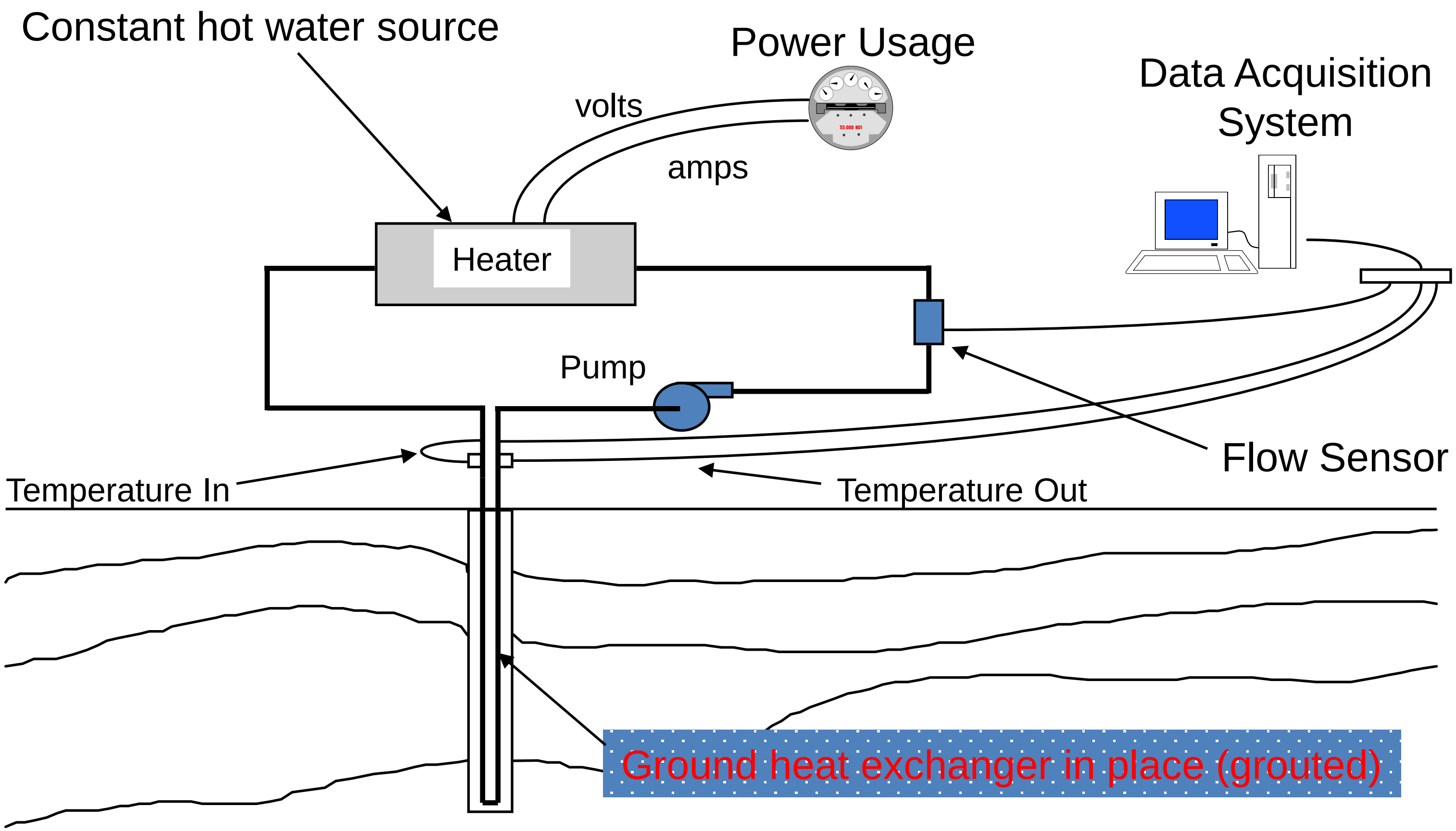
  Heat exchanger installed (includes grout, spacer, etc.)

  Thermal load placed on loop

  Time - Temperature curve developed

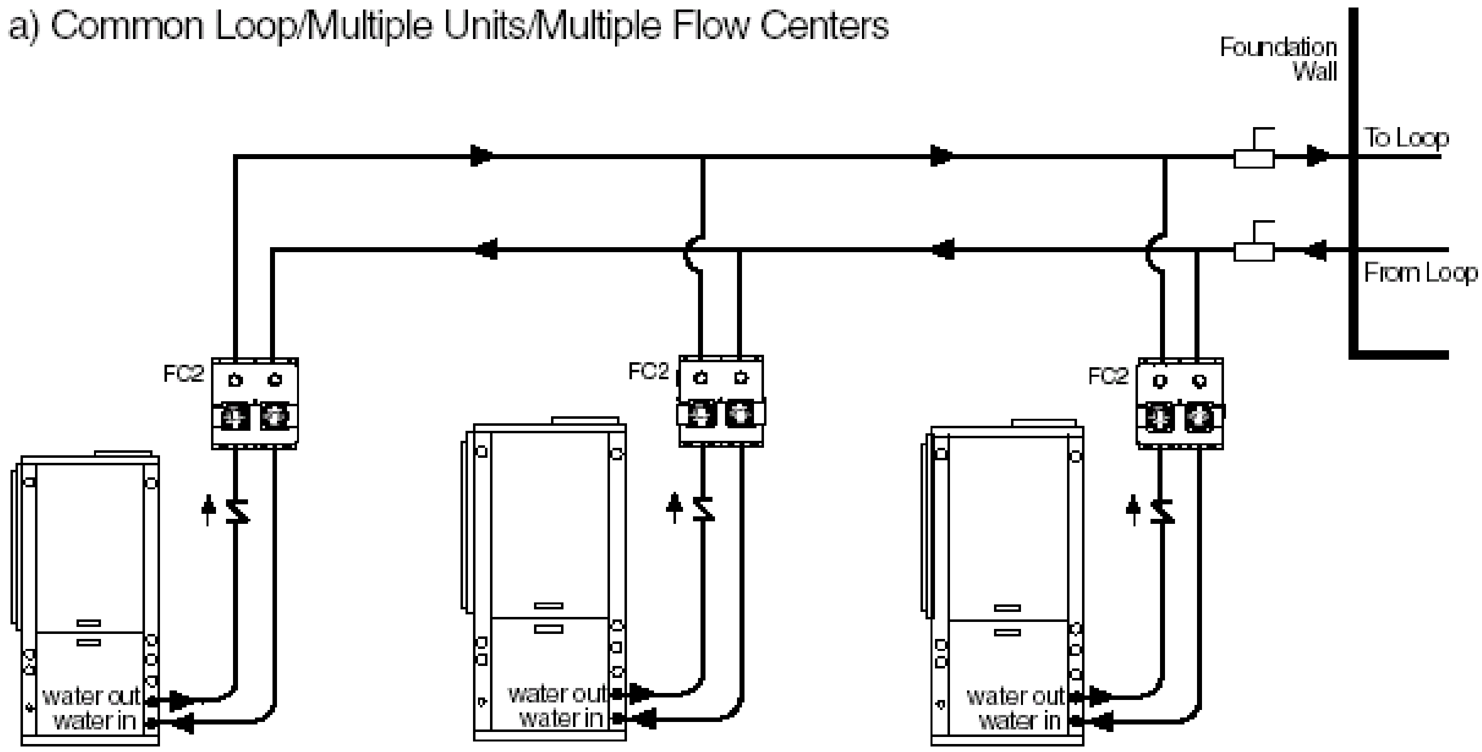
  Thermal conductivity derived

In-situ Test System Schematic



Thermal Testing

Pump Room Example



Heat Pumps

Pump Room

Considerations for using GSHP at MCP Sites – Open Loop

1. Open Loop systems very risky – may worsen environmental impact.
2. Most likely will not be issued a permit from the UIC program.
3. Standing Column Wells may work if “no bleed” but must be installed in areas of the site with minimal impact.
4. May require RAM Plan (soil and groundwater management plan) depending on MCP phase.
5. Recommend employing LSP to evaluate potential impacts if owner/developer considering installing open loop system.

Considerations for using GSHP at MCP Sites – Closed Loop

1. Closed Loop systems less risky – have less environmental impact.
2. May be installed at sites with AUL-depending on location and concentration levels of contaminates.
3. Will soil and groundwater management plan
4. Recommend employing LSP to evaluate potential impacts if owner/developer considering installing closed loop system.

Course Objectives

1. Provide an understanding of geothermal design principles as they relate to potential environmental issues
2. How environmental conditions impact the design of geothermal systems
3. Determine feasibility of installing geothermal systems at impacted and MCP sites.

Conclusions

1. Get environmental professional with geothermal experience involved early in the design.
2. Person conducting feasibility evaluation must have understanding the method of geothermal earth couples and how subsurface conditions could be affected.
3. Evaluate Permit requirements.
4. Environmental conditions can be managed.
5. Not all sites are appropriate for geothermal.